TITLE: Oscillating 65 Deg. Delta Wing, Numerical

17C. OSCILLATING 65° DELTA WING, NUMERICAL

Willy Fritz
DaimlerChrysler Aerospace
Military Aircraft
81663 Munich (Ottobrunn)
Germany

INTRODUCTION

This data set consists of steady and unsteady numerical solutions of a sharp-edged cropped delta wing with a leading edge sweep of 65° undergoing a pitching oscillation. The geometry of the wing corresponds with the geometry of the wind tunnel model described in the previous data set (chapter 17E), the difference being the absence of the fuselage in the numerical model. The presence of the fuselage on the upper surface flow is believed to have an effect at small angles of attack only on the forward region of the wing and to have an effect on the location of vortex breakdown at large angles of attack.
The pitching oscillation has an amplitude of 3°, the mean angle of attack is 9°. The position of the oscillation axis and the reduced frequency have been set to match one of the reduced frequencies of the aforementioned experiment, while the Mach number has been increased from the experiment's Mach number 0.12 to 0.4 to reduce computational time.
The data set includes field solutions from Euler as well as from Reynolds averaged Navier-Stokes (RANS) calculations for four equidistant instants within one oscillation cycle and for the corresponding static solution ($\alpha = 9°$). Comparison of the Euler and RANS solutions shows the well known differences in strength and spanwise location of the primary vortex-induced suction peak due to the absence of a secondary vortex in the Euler solution. The agreement with the experimental results is very good.

LIST OF SYMBOLS AND DEFINITIONS

C_p	static pressure coefficient, $C_p = (p-p_\infty)/q_\infty$
LE	leading edge
M_∞	freestream Mach number
RANS	Reynolds averaged Navier-Stokes
Re_∞	Reynolds number
TE	trailing edge
T_∞	freestream temperature
U_∞	freestream velocity
$b = 2s$	wing span
c_i	root chord
f_0	model oscillation frequency
q_∞	dynamic pressure
α	angle of attack, degrees
α_0	mean angle of attack, degrees
$\Delta\alpha$	oscillation amplitude
β	angle of sideslip
ω^*	reduced frequency, $\omega^* = 2\pi f_0 c_i/U_\infty$

FORMULARY

1 General description of model

1.1 Designation	VFE WB1 - SLE
1.2 Type	cropped delta wing
1.3 Derivation	NLR 65°-wing,
1.4 Additional remarks	none
1.5 References	1

2 Model geometry

2.1 Planform	cropped delta wing, see Fig. 1
2.2 Aspect ratio	1.378
2.3 Leading edge sweep	65°
2.4 Trailing edge sweep	0°
2.5 Taper ratio	0.15
2.6 Twist	0°
2.7 Root chord	1.0

2.8 Semi span of model	0.3964
2.9 Area of planform	0.4558
2.10 Definition of profiles	symmetrical with sharp leading edge; 5% rel. thickness; arc segment from LE to x/c = 0.4; airfoil NACA 64A005 from x/c = 0.4 to x/c = 0.75; straight line with 3° inclination from x/c = 0.75 to TE, see Fig. 4
2.11 Lofting procedure between reference sections	N/A
2.12 Form of wing-body junction	N/A, no fuselage
2.13 Form of wing tip	rounded, see Fig. 2
2.14 Control surface details	N/A
2.15 Grid type	structured grid
2.16 Grid size	Euler grid: 96 * 32 * 80 cells RANS grid: 192 * 80 * 128 cells
2.17 Additional remarks	Euler grid identical with WEAG-TA 15 CE III "Fine Grid"
2.18 References on model geometry	1

3 CFD code used

3.1 Euler code	DASA code, using modified Jameson type scheme (dual timestepping)
3.2 RANS code	FLOWer Version 112.1 using modified Jameson type scheme (dual timestepping)
3.3 Turbulence model	Baldwin-Lomax with Degani-Schiff modification, no fixed transition
3.4 Computational time	Euler: 6-8 hours per oscillation cycle RANS: 60 hours per oscillation cycle on a SGI Power Challenge, 1 processor used
3.5 Additional remarks	unsteady calculation started with steady solution ($\alpha = 9°$), unsteady solution converged after 2 - 3 model oscillation cycles
3.6 References on CFD code	2

4 Model motion

4.1 Mode of applied motion	sinusoidal pitching motion about axis parallel to model Y-axis. Axis location: $x/c_i = 0.5625$, axis located below wing plane, $z/c_i = 0.042$
4.2 Range of amplitude	$\Delta\alpha = 3°, 6°$
4.3 Range of frequency	$\omega^* = 2\pi f_0 c_i/U_\infty = 0.56$
4.4 Additional remarks	none

5 Boundary conditions

5.1 Mach number	0.4
5.2 Total pressure	atmospheric
5.3 Temperature	T = 300 K
5.4 Range of model incidence	$\alpha_0 = 9°$
5.5 Definition of model incidence	model incidence defined relative to the wing plane
5.6 Position of transition, if free	N/A
5.7 Additional remarks	distance of far field $\pm 3 \cdot c_i$ in x direction, $6 \cdot s$ in y direction, $\pm 3 \cdot c_i$ in z direction

6 Data presentation

6.1 Test cases for which data could be made available	$\alpha = 9°$, $\Delta\alpha = 3°$ and $\Delta\alpha = 6°$, $Re = 3.1 \cdot 10^6$, $\omega^* = 0.56$, Ma = 0.4, Euler and RANS solutions
6.2 Test cases for which data are included in this document	$\alpha = 9°$, $\Delta\alpha = 3°$, $Re = 3.1*10^6$, $\omega^* = 0.56$, Ma = 0.4, Euler and RANS solutions
6.3 Variables included	x, y, z, u/U_∞, v/U_∞, w/U_∞, C_p, total pressure loss, enthalpy

6.4 Data available as	field solution for $\alpha = 9°$ static case, $\alpha = 9°$ dynamic case (upstroke), $\alpha = 12°$ dynamic case, $\alpha = 9°$ dynamic case (downstroke), $\alpha = 6°$ dynamic case, see Fig. 3.
6.5 Steady forces and moments	no
6.6 Unsteady forces and moments	no
6.7 Other forms in which data could be made available	no
6.8 References on data presentation	3, 4
6.9 Additional remarks	data of RANS solution available for every other grid point in each direction. Data for Euler and RANS solutions formatted as TECPLOT® input file

7 Comments on data

7.1 Accuracy	2nd order in time, 2nd order spatial (Euler and RANS)
7.2 Other relevant calculations on same model	none, but unsteady Euler calculations on the presented grid for the cases $\alpha = 9° \pm 6°$ and $\alpha = 21° \pm 6°$ are part of the CE IV of WEAG TA-15
7.3 Relevant calculations on other models of nominally the same airfoil	no, but comparison of RANS results with experimental data of same dynamic parameters from chapter 17E1 is shown in Fig. 5.

Personal contact for further information

Willy Fritz
DaimlerChrysler Aerospace
Dept. MT63 Build. 70.N
P.O. Box 80 11 60
81663 Munich, Germany
Phone: +49-(0)89-607-24529
Email: Willy.Fritz@m.dasa.de

List of references

1 M. T. Arthur: WEAG TA 15 Common Exercise III on Grid Adaptation in Vortical Flow Simulations; Part 1: Euler Solutions. DRA/AS/ASD/TR96073/1, April 1997

2 N. Kroll, R. Radespiel, C.-C. Rossow: Accurate and Efficient Flow Solvers for 3D Applications on Structured Meshes. Lecture Series 1994-05 of the von Karman Institute for Fluid Dynamics, March 1994

3 W. Fritz: Numerische Simulation der instationären Strömung um hochangestellte, oszillierende Deltaflügel. 10. DGLR Fach-Symposium "Strömungen mit Ablösung", Braunschweig, Nov.11th - Nov. 13th 1996

4 W. Fritz: Unsteady Navier-Stokes calculations for a delta wing oscillating in pitch. ICAS-98, Melbourne, Sept. 1998

FORMAT OF DATA SET

As mentioned in section 6.9, the data set is submitted as a series of TECPLOT® input files The files are ASCII files, their size has been reduced with the UNIX command `compress` . The contents of the files can be deduced from their names, all files containing Euler solutions start with the letters eu_, whereas all files containing Navier-Stokes solutions start with the letters `ns_`. The numbers following those letters indicate the angle of attack. Finally, the letters _up indicate upstroke movement (α increasing) of the model, the letters _dn indicate downstroke movement and the letters `_st` indicate a steady solution.
As an example, the first lines of an arbitrary data file are printed below. Three columns have been omitted.

```
TITLE = "TA15 Delta Wing 3D-Volume Data"
VARIABLES = "X", "Y", "Z", "U", "V", "W", "CP" ,"TPL", "ENTP"
ZONE F=POINT, I=        97 J=          33K=        81
   0.00000E+00    0.00000E+00    0.00000E+00    0.70126E+00    -0.52673E-01 ... -0.59724E-01
   0.13577E-02    0.17011E-03    0.12071E-14    0.82930E+00    -0.11842E+00 ... -0.10498E+00
   0.28747E-02    0.35948E-03    0.24797E-14    0.93920E+00    -0.98587E-01 ... -0.13640E+00
   0.45697E-02    0.57019E-03    0.38084E-14    0.99580E+00    -0.61080E-01 ... -0.15771E+00
   0.64634E-02    0.80454E-03    0.51794E-14    0.10214E+01    -0.29753E-01 ... -0.17151E+00
   0.85793E-02    0.10650E-02    0.65733E-14    0.10340E+01    -0.80058E-02 ... -0.17954E+00
   0.10943E-01    0.13544E-02    0.79636E-14    0.10422E+01     0.62073E-02 ... -0.18298E+00
   0.13585E-01    0.16756E-02    0.93157E-14    0.10491E+01     0.15155E-01 ... -0.18273E+00
   0.16536E-01    0.20318E-02    0.10585E-13    0.10556E+01     0.20517E-01 ... -0.17949E+00
```

Since the data are written as ASCII files, they can be read by any other program using the Fortran 77 code fragment below. In the data files each row of data corresponds to a data point and each column corresponds to a variable. The order of the variables is specified in one of the first rows, starting with the tecplot-specific keyword VARIABLES. The dimensions in i-, j- and k-direction are specified in the line starting with the keyword ZONE.

```
      do 1, kmax
        do 1, jmax
```

```
            do 1, imax
                do 1, var = 1, numvar
                    read *, array(var, i, j, k)
                end do
            end do
        end do
    end do
```

FIGURES

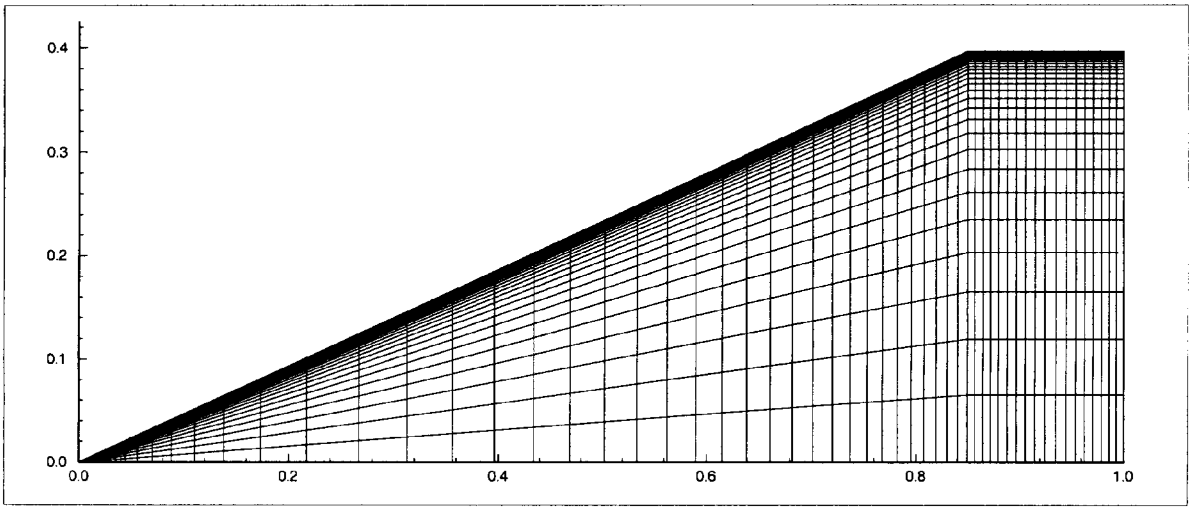

Figure 1: Geometry of the delta wing, RANS grid, every other gridline shown

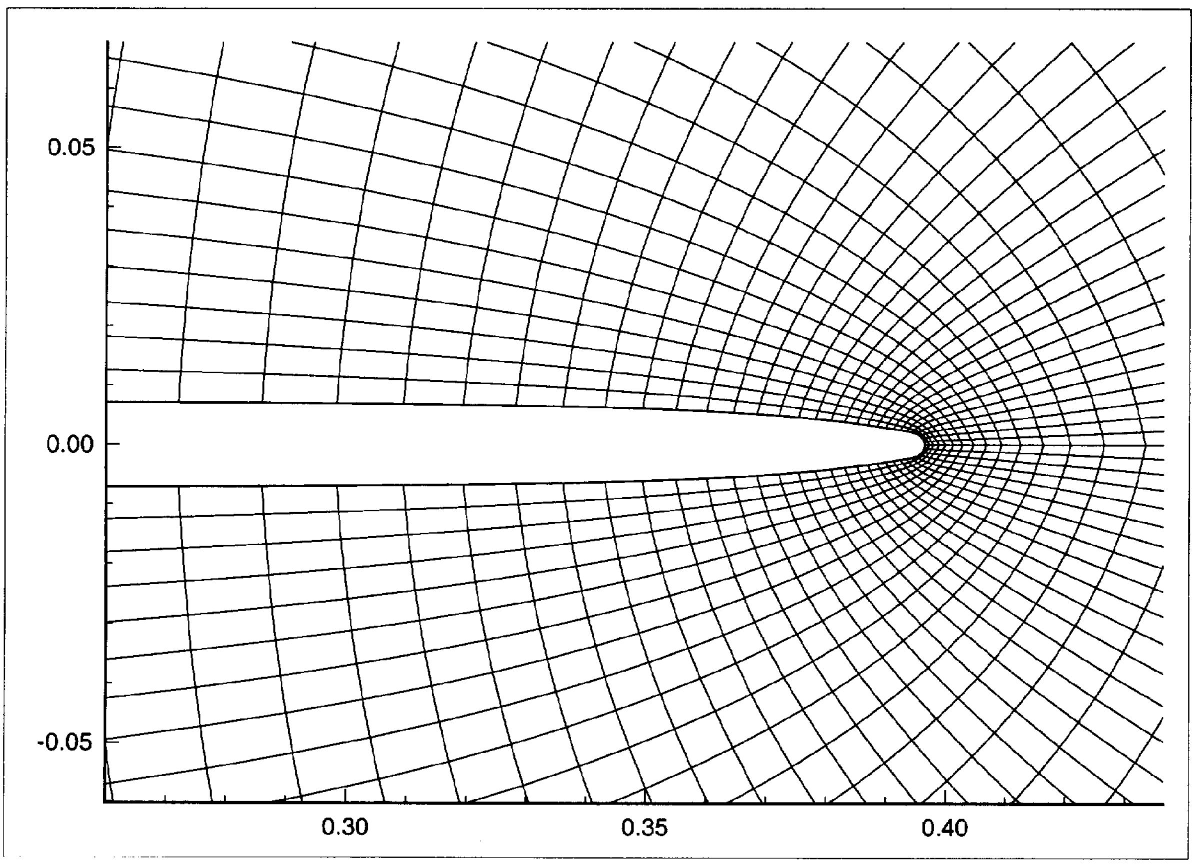

Figure 2: Geometry of wingtip at $x/c_i = 0.9$, Euler grid

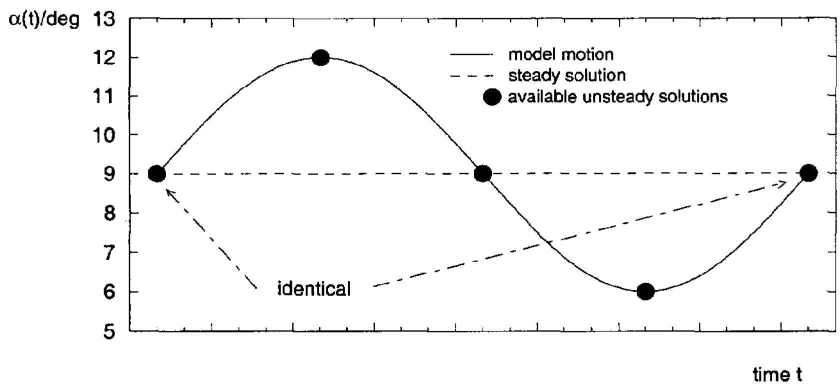

Figure 3: Available steady and unsteady solutions

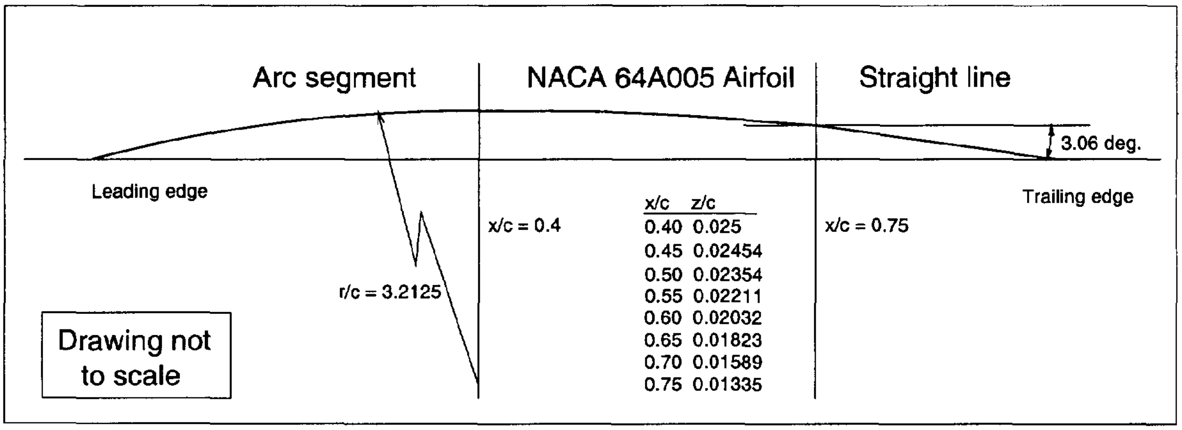

Figure 4: Definition of airfoil

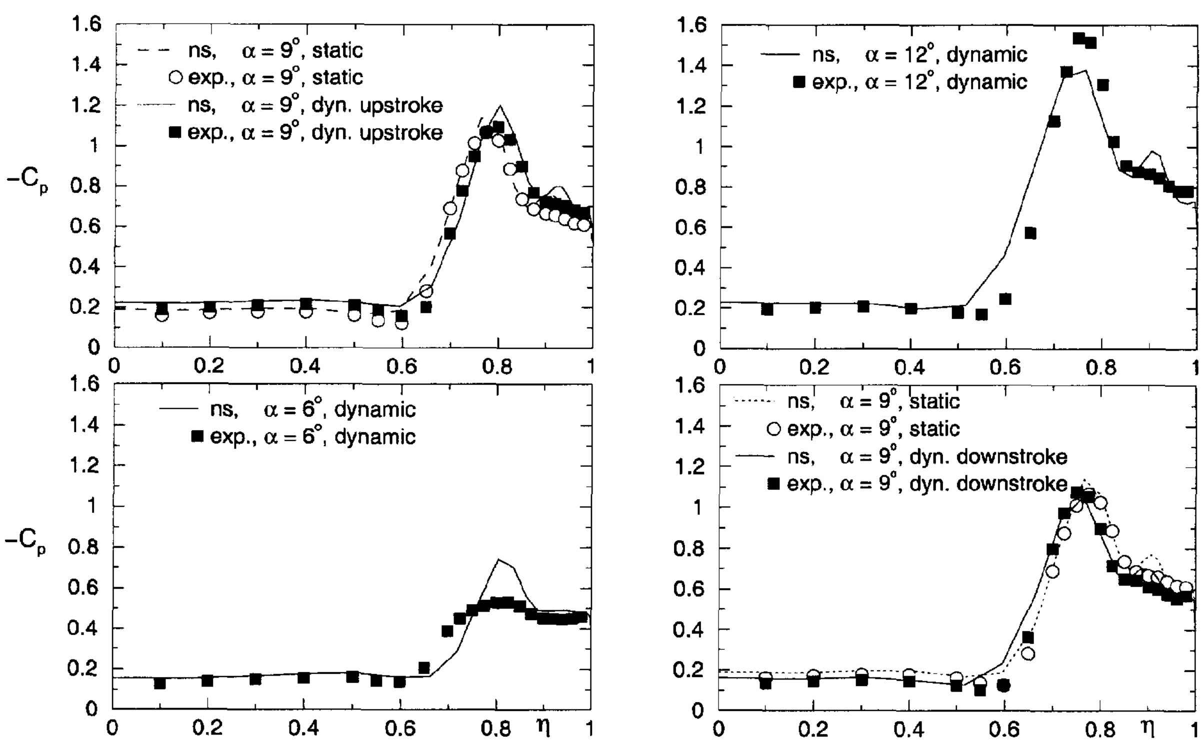

Figure 5: Comparison of results from RANS calculation with experimental data ($\alpha = 9°$, $\Delta\alpha = 3°$, $\omega^* = 0.56$)